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Effects of feeding strategies on growth of Florida pompano (Trachinotus carolinus) in closed recirculating systems

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EFFECTS OF FEEDING STRATEGIES ON GROWTH OF FLORIDA POMPANO (*TRACHINOTUS CAROLINUS)* IN CLOSED RECIRCULATING SYSTEMS

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ABSTRACT

Due to its high market value, Florida pompano (*Trachinotus carolinus*) has long been regarded as a promising species for aquaculture. Although pompano exhibit several favorable traits for culture, previous studies have indicated that fish larger than 200 g exhibit poor growth. This study was conducted to determine the effects of different feeding strategies on production characteristics of pompano raised in closed recirculating systems.

Results of Experiment 1 indicated that mean weight of fish (initial mean weight, 17 g) fed a fixed ration at two and six feedings per day was greater than that of fish fed only once per day. Weight gain of fish fed twice per day was greater than that of fish fed once per day. Results of Experiment 2 revealed that growth was not greatly affected by the stocking densities evaluated (1.3 and 2.6 kg/m^3). However, mean weight and weight gain of fish (initial mean weight, 74 g) fed to satiation were greater than that of fish fed a fixed ration and reared at the low density. Results of Experiment 3 demonstrated that mean weight and weight gain of fish (initial mean weight, 215 g) reared to market size while receiving four feedings to apparent satiation per day was greater than that of fish receiving two feedings to apparent satiation per day. Whole body composition analysis revealed exceedingly high lipid levels of fish throughout the study. Market size pompano had dressed carcass yields greater than 70% and fillet yields greater than 45%. Feeding strategies used in this study had little, if any effects on feed efficiencies and specific growth rates. Survival of fish in each experiment was greater than 90%.

Growth of pompano in this study was not restricted to 200 g. Pompano achieved market size after approximately 4.5 months and reached an average weight of 712 g after approximately 8.5 months. Our results show that market-size pompano can be grown from juveniles in closed recirculating systems under the conditions used in this study.

CHAPTER 1
INTRODUCTION

Biology

Florida pompano (*Trachinotus carolinus*), hereafter referred to as “pompano”, is a member of the jack family (Carangidae), order Perciformes, and class Actinopterygii (ray-finned fishes). Other species of interest of the genus *Trachinotus* include Atlantic permit (*T. falcatus*), palometa (*T. goodie*), snubnose pompano (*T. blochii*), longfin pompano (*T. goreensis*), and derbio (*T. ovatus*). The African pompano (*Alectis cilaris*) is also a member of the Carangidae family.

Pompano have a silver-colored body with a bluish-green hue on the dorsal side. Sometimes, a yellow tint on the stomach and lower parts of the head also is present. Anal and caudal fins are usually yellow. The body is compressed, with similar upper and lower profiles. The head slopes to a blunt snout. Pompano possess subterminal, protrusible mouthparts, and short, widely spaced gill rakers (Bellinger and Avault 1971). These morphological features allow fish to efficiently root through sand to prey on benthic organisms. The jaws contain very small teeth, but no teeth are present on the tongue at any life stage (Gilbert and Parsons 1986). Scales are very small, smooth and partially embedded. Pompano have been estimated to live for three to four years, reaching weights of 2.2–3.6 kg, though pompano over 1.8 kg are rarely caught (Fields 1962, Gilbert and Parsons 1986).

Pompano are found in schools in the coastal waters of the Atlantic Ocean from Massachusetts to Brazil and throughout the Gulf of Mexico. This species is especially common along the Florida coasts (Gilbert and Parsons 1986, Watanabe 1994). Atlantic permit, a prized gamefish, and palometa also are found in the pompano’s geographic range. Permit are often mistaken for pompano by anglers. However, permit grow considerably larger than pompano, reaching sizes up to 13.6 kg (Gilbert and Parsons 1986). The palometa has elongated dorsal and anal fins, and distinct dark bars on the dorsal, anal, and caudal fins, which distinguish this species from pompano.

Pompano, a warm-water fish, is normally caught in water ranging from 25 to 32 C (Watanabe 1994). Few pompano are caught at water temperatures below 17 C (Gilbert and Parsons 1986). Adult pompano are commonly caught in water with salinities ranging from 30 to 37 g/L (Finucane 1969, Gilbert and Parsons 1986). Juveniles appear to tolerate a wider range of salinities than adults. They have been captured in water with salinities as low as 9 g/L and as high as 50 g/L (Finucane 1969, Perret at al. 1971, Gilbert and Parsons 1986).

Small juvenile pompano are apparently opportunistic feeders (Bellinger and Avault 1971). Juvenile pompano collected in the surf zone of the Mississippi coast were observed to be planktivores, primarily consuming copepods and some benthic organisms including polychaetes, coquina clam siphons (*Donax variabilis*), and mole crabs (*Emerita talpoida*) (Modde and Ross 1983). In Florida, juveniles collected in the surf zone were shown to be mainly bottom feeders, consuming coquina clam siphons and mole crabs (Armitage and Alevizon 1980). Juvenile pompano collected at Louisiana beaches were observed to consume polychaetes, bivalves, amphipods, and penaeid shrimp (Bellinger and Avault 1971).

Adult pompano appear to be selective grazers, feeding mostly on the bottom on a wide variety of organisms (Bellinger and Avault 1971). As pompano grow, pharyngeal plates develop that allow consumption of hard-shelled organisms including clams, mussels, and crabs (Bellinger and Avault 1971). Bivalves, crabs, shrimp, and various fish species constitute the majority of the diet of adult pompano (Iverson and Berry 1969, Finucane 1969).

Little is known of the natural spawning behavior of pompano. Spawning has not been observed in nature, so speculation on spawning habits is based on collection locations of larvae, juveniles, and mature adults. It is believed that spawning occurs off the coast of the southeastern United States from February through September (Fields 1962, Berry and Iverson 1967, Iverson and Berry 1969). Spawning may occur year round in the tropical regions of the Gulf of Mexico and the Caribbean Sea (Berry and Iverson 1967). Opinions differ as to whether pompano spawn near shore or far offshore. Pompano larvae have been collected 24 km off the western shore of Florida and 98 km off the coast of South Carolina (Fields 1962, Finucane 1969). It is believed that larvae spend approximately the first month of life at sea (Fields 1962), then begin moving toward shore, where they congregate in the surf zone of low-energy beaches. Juveniles appear near beaches from April to November, but are most abundant from May to June (Fields 1962, Moe et al. 1968, Bellinger 1969). Large numbers of juveniles can be easily collected using a seine on open beaches in many areas (Gilbert and Parsons 1986). Juveniles in Florida begin to leave the surf zone when they have grown to a body length of approximately 150 mm, while juveniles in Georgia begin vacating the surf zone at body lengths of 60-70 mm (Fields 1962, Iverson and Berry 1969). Temperature may play a role in determining the time of departure, since few juveniles are found near beaches when the water temperature has reached 19 C (Fields 1962). Adult pompano are usually found in shallow water near the surf zone. However, sexually mature adults also have been caught in deeper (up to 60 m), offshore waters (Shipp and Hopkins 1978).

Pompano is considered one of the most desirable food fishes and it commands a significantly higher price than many other marine and freshwater species. In 2000, the average wholesale price of whole pompano was $9.10/kg (NMFS 2000). Depending on time of year and availability, the price of pompano fillets can reach $35/kg (McMaster 1988, Watanabe 1994). A significant sport and commercial fishery for pompano exists along the south Atlantic and Gulf coasts of the United States, with 83-92 % of landings occurring in Florida (Watanabe 1994). Despite the high demand, commercial catches have traditionally been low when compared to total US commercial landings. From 1989 to 1999, commercial landings of pompano averaged less than 350,000 kg per year, with a value slightly more than $2 million (NMFS 1999).

Previous Pompano Research

High market value, availability of wild fry, and low commercial landings were major factors that attracted researchers and investors to investigate the feasibility of pompano aquaculture. The first documented attempt of culturing pompano occurred at Marineland, Florida between 1952 and 1955 (Berry and Iverson 1967, Cuevas 1978, Watanabe 1994). Juvenile pompano (0.5-9 g) were stocked into brackish-water, earthen ponds (0.02-0.05 ha) at rates of 1,298-4,950 fish/ha. Fish were fed a diet of ground trash fish (commercial by-catch). Fish reached weights of 100-270 g in 65-133 d, with pond yields of 270-438 kg/ha. Between 1957 and 1960 numerous attempts to raise pompano fry in ponds near St. Augustine, Florida failed for various reasons, including low temperature, pond flooding, escape, and oxygen depletion due to overstocking (Berry and Iverson 1967). In 1961, a 0.2-ha pond stocked with 1,500 fry produced 700 fish averaging 500 g in size (Berry and Iverson 1967). However, it took 15 months to raise fish to this size and the trial was terminated soon after, due to a die-off.

In the 1960s, research conducted by government agencies and universities led to the development of commercial facilities for pompano culture throughout Florida. The best documented of these early commercial attempts was by Minorcan Seafood, located near Marineland, Florida, from 1963-1967 (Moe et al. 1968). Wild-caught juvenile pompano were raised in earthen ponds (0.2-0.6 ha) supplied with tidal water and were fed ground trash fish. Though it was believed that approximately 100,000 large pompano were present, only 1,781 were harvested. In 1967, rearing activities ceased due to low yields (Moe et al. 1968).

In the 1960s, pompano culture was evaluated using a variety of production systems. Cage culture was investigated by Tatum (1972, 1973) in Alabama. Cylindrical cages placed in brackish water ponds were stocked with juvenile pompano (mean weight, 4 g) at densities of 392 or 654 fish/m^3 (Tatum 1972). Fish were fed one of two diets: a commercially prepared 40%-protein trout chow or ground trash fish mixed with 30% soybean meal. Growth, feed conversion ratio (FCR), and survival were higher in fish fed the trout chow. Nontheless, FCR values (3.3-3.4) were poor.

In a subsequent study, juvenile pompano (mean weight, 12 g) were stocked in cages at densities ranging from 263-657 fish/m^3 (Tatum 1973). Fish were fed a 40%-protein trout chow for 103 days resulting in yields ranging from 27.8-46.1 kg/m^3. As in the previous study, survival rates were high (80-88%), but FCR values were poor (2.7-3.6).

Cage culture of pompano in intake and discharge canals of power plants was investigated in Texas (Marcello and Strawn 1972) and Florida (Smith 1973). In Texas, juvenile pompano (57.5-74.9 g) were stocked into 1.0-m^3 floating cages at densities of 25 fish/m^3. Water temperature ranged from 5.5-31 C and salinities from 2.6-23 g/L. Fish were fed a 40%-protein trout chow for 85 to 107 days and final body weight ranged from 119-198 g. While survival rates were high (85-100 %), yields were low (2.1-4.0 kg/m^3) and FCR values were poor (3.3-5.9).

In Florida, juvenile pompano (mean weight, 7 g) were stocked in 1.0-m^3 cages at densities of 100-900 fish/m^3 (Smith 1973). Cages were located in a man-made lake that received heated effluent from a power plant. Fish were fed a 40%-protein trout pellet for 272 days. Final weight ranged from 160 to 214 g. Survival rate~~s~~ (80-84 %) and yields (18-115 kg/m^3) were high, but FCR was poor (4.45).

In Alabama, approximately 5,000 juvenile pompano were stocked into cages in brackish water (Swingle 1972). Fish were stocked in one of five size classes (2, 5, 8, 30, and 94 g). After approximately 128 days, FCR averaged 5.4 and survival averaged 30%. It was speculated that escape, cold weather, and poor feeding practices were reasons for the observed poor growth and survival.

Pond culture was the most popular means of raising pompano in early trials. Not only did many commercial facilities attempt to raise pompano in ponds, a number of research studies were conducted in earthen ponds. Tatum and Trimble (1978) stocked juvenile pompano in 0.08-ha brackish-water ponds at rates of 8,750 or 10,412 fish/ha. Fish were fed a 40%-protein trout chow for 95-191 days. Pond yields averaged 564 kg/ha; survival (42%) was low, and FCR (3.0) was high.

In an attempt to increase pond yield, polyculture of pompano and shrimp was investigated (Tatum and Trimble 1978). Juvenile pompano (0.5 g) were stocked into a 0.08-ha brackish-water pond at a rate of 10,412 fish/ha. Post-larval brown shrimp (*Penaeus aztecus*), too large for the pompano to consume, were stocked at a density of 31,250/ha. After 146-150 days, pompano yields averaged 593 kg/ha and shrimp yield~~s~~ averaged 222 kg/ha. Survival rates were 30% for pompano and 53% for shrimp. Combined FCR for both species was 2.6.

Trials comparing pompano monoculture with pompano-shrimp polyculture were also conducted (Trimble 1980). In both monoculture and polyculture experiments, juvenile pompano (5 g) were stocked into 0.08-ha, brackish-water ponds at a density of 10,000 fish/ha. In polyculture ponds, juvenile blue shrimp (*P. stylirostris*) were stocked at a density of 82,813/ha. After 106 days, monocultured pompano attained a mean weight of 106 g and yields averaged 741 kg/ha. Survival was 67% and FCR was 3.9. Polycultured pompano were harvested after 105 days and shrimp were harvested after 148 days. Final mean weights were 74 g for pompano and 14 g for shrimp. Survival of pompano was 74% and combined FCR for pompano and shrimp was 3.0.

Little work has been done with tank culture of pompano. The first attempted tank culture was apparently done at the Miami Seaquarium in 1968 (Iverson and Berry 1969). Wild-caught juvenile pompano (5 g) were stocked into 42-m^3 tanks at a rate of 24 fish/m^3. Tanks were supplied with natural seawater. Pompano were fed a mixture of ground trash fish and a 40%-protein trout diet. After 137 days, mean fish weight was 203 g and average tank yield was 2.9 kg/m^3. Survival was 60%.

Tank polyculture with red-spotted shrimp (*P. brasiliensis*) has been studied in Venezuela (Gomez and Scelzo 1982). Juvenile pompano and shrimp were stocked into 28-m^3 tanks at rates of 10/m^3. A pelleted diet containing 60% crude protein was fed. Pompano weights after 75 days averaged 41 g. Survival was low (17%) and FCR was exceedingly poor (6.6). In a subsequent experiment, pompano were stocked at a density of 5/m^3 and shrimp at 10/m^3. The diet used was laboratory formulated and provided 43% crude protein. Survival after 75 days was 64% and combined FCR was 3.1.

Temperature tolerance was a focus of many of the early studies. Pond studies conducted by Moe et al. (1968) show that pompano began to exhibit a stress response at 12 C and 33 g/L. At 10 C and 33 g/L, almost complete mortality was observed. Under controlled laboratory conditions, pompano have been shown to tolerate a reduction in temperature from 29 C to 9 C at

33 g/L salinity (Kumpf 1971). At the same salinity (33 g/L) and initial temperature (29 C), pompano were able to tolerate an increase in temperature to 36.5-39.5 C. Temperature tolerance appears to be affected by salinity, because increasing or decreasing salinity (from 33 g/L) causes a decrease in the range of temperature tolerance (Kumpf 1971). At salinities of 15-20 g/L, juvenile pompano were able to tolerate a reduction in temperature from 26.8-28 C to 19-21 C (Kumpf 1971).

Several studies have been conducted regarding salinity tolerance of pompano. The 72-hour LC_{50} of wild-caught pompano captured at 23 g/l was 3.5 g/L (Allen and Avault 1970). The 72-hour LC_{50} of the same wild-caught pompano acclimated for 12 days at 5 g/L was 1 g/L. Allen and Avault (1970) also observed that juvenile pompano were able to grow at a salinity of 5 g/L. At temperatures of 22-27 C and an initial salinity of 32-33 g/L, juvenile pompano were able to tolerate salinities as low as 2 g/L and as high as 45 g/L (Kumpf 1971).

In most initial studies, pompano were fed a 40%-protein trout feed supplemented with ground trash fish. This diet was shown to be more effective than ground fish mixed with soybean meal (Tatum 1972). More recently, studies have been conducted to determine the dietary composition that pompano require for optimal growth. Juvenile pompano fed diets with 34% digestible protein and lipid levels of 4 or 8% exhibited increased growth relative to fish fed diets with higher or lower lipid levels (Williams et al. 1985). Juvenile pompano fed diets with 8% lipid exhibited increased growth and feed efficiencies when fed increased levels of protein (Lazo et al. 1998). These studies suggest that the optimal digestible energy-to-protein ratio for pompano is between 7.4 and 8.1.

Limited information also exists with respect to captive spawning of pompano. The first successful hormone-induced spawning of pompano in captivity was reported by Hoff (1972, 1978a, b). Out of season gonadal maturation, through photoperiod manipulation and hormone treatments, also has been accomplished on a small scale (Hoff 1972, 1978a).

In 1973, a private company, Oceanography Mariculture Industries, Inc. (OMI), built a pompano farm in the Dominican Republic. The goal of OMI was to establish technology that would yield a known amount of saleable pompano on a monthly basis (McMaster 1988). To accomplish this goal it would be necessary to produce pompano eggs from OMI broodstock 52 weeks per year and develop techniques to rear the larvae. Such methods were developed and larvae were reared on a commercial scale year-round. Selected pompano from the first spawn at OMI were used to spawn second-generation fish. It was found that at a body weight of 150-200 g the pompano exhibited a sudden increase in food conversion and growth slowed drastically. The reason for this phenomenon was unknown. In 1973, operations at OMI ceased for reasons beyond the control of the company.

Current Status

Because the US aquaculture industry is predominately freshwater-based, a significant amount of research has been conducted to develop and improve production of species, such as channel catfish (*Ictalurus punctatus*) and rainbow trout (*Oncorhynchus mykiss*). In contrast, relatively little information is available on optimal culture methods for marine and estuarine species (Finucane 1970). Preliminary studies with pompano revealed this species exhibits many favorable traits for aquaculture: it adapts to intensive culture systems, readily accepts pelleted feed, tolerates a wide range of salinities, and has high initial growth rates. Although initial studies suggested that pompano culture could be a viable enterprise, commercial operations were not successful. The general opinion of researchers and commercial producers who have experience with pompano is that two major obstacles - lack of cold tolerance and slow growth of large fish - have prevented successful commercialization.

Pompano are intolerant of water temperatures below 10 C (Moe et al. 1968, Allen and Avault 1970). This makes open-water culture without over-wintering facilities risky, even in the southernmost USA. Pompano also have been reported to grow slowly and have poor feed conversion rates at body weights greater than 200 g (Jory et al. 1985, Williams et al. 1985, McMaster 1988, Watanabe 1994, Lazo et al. 1998). Although the reason for this phenomenon is unknown, reduced growth of larger fish could have been caused by poor environmental conditions, inadequate diets, and suboptimal feeding rates in early culture facilities, rather than limited growth potential of pompano.

New technologies have been developed that allow much greater control of temperature and other water quality variables in culture systems than was possible a decade ago. Indoor and greenhouse-based, closed recirculating systems are one such advancement. A considerable amount of research has been conducted to develop and refine biofiltration systems for aquaculture, such as the bead filter. Bead filters that provide both solids capture and nitrification are now used by a number of aquaculture facilities. Bead filters have a high carrying capacity that is well suited for a variety of recirculating system applications (Malone and Beecher 2000). Advanced recirculating systems have been developed for several aquatic species including tilapia (*Oreochromis* spp.), hybrid striped bass (*Morone saxatilis* X *M. chrysops*), and the American alligator (*Alligator mississipiensis*).

Diets used in initial pompano production trials consisted mainly of ground fish, pelleted trout and catfish feeds, or a mixture of both. It is quite possible that these diets did not satisfy the nutritional requirements of this marine finfish species. A number of advancements in fish nutrition now allow feeds to be formulated to meet the specific nutritional requirements of a given species. As a result, many feeds are now available to meet the energy demands of highly active, rapidly growing, marine species. However, the specific nutritional requirements of pompano are still unknown.

In addition to diet quality, feeding practices may affect growth of pompano. Juvenile pompano have been shown to feed throughout the day when given unlimited access to food items (Heilman and Spieler 1999). Given their natural pattern of food consumption, the pompano digestive tract may function most efficiently when fish receive smaller quantities of food several times per day. Thus, multiple feedings might enhance growth and feed conversion.

Stocking density may also affect growth of pompano. Stocking density studies conducted with juvenile, mid-water species such as turbot (*Scophthalmus maximus*), red porgy (*Pagrus Pagrus*), European sea bass (*Dicentrarchus labrax*), and gilthead sea bream (*Sparus aurata*) have yielded varying results. Juvenile red porgy and turbot exhibited higher growth rates when held at relatively low densities (0.7-1.1 kg/m^3) (Maragoudaki et al. 1999, Irwin et al. 1999). However, European sea bass attained significantly higher growth rates when stocked at high densities (2-4 kg/m^3) (Papoutsoglou et al. 1998). Because pompano exhibit strong schooling behavior, similar to that of European sea bass, it is possible that growth of pompano could be increased at moderate to high stocking densities. However, because pompano are extremely active fish, elevated stocking densities could induce stress and cause growth inhibition.

The purpose of this study was to evaluate the effects of feeding frequency, feeding rate, and stocking density on production characteristics of pompano reared in closed recirculating systems. The study consisted of three laboratory feeding trials designed to address each objective. The ultimate goal of this study was to raise market-size pompano in a closed system.

Chapter 2
Initial Protocol

Juvenile pompano (~5 g) were collected by seine on the beaches of Port Fourchon, Louisiana during late summer and early fall of 2000. Approximately 4,000 fish were captured during a six-week period. After capture, fish were transported to the Louisiana Universities Marine Consortium (LUMCON), Cocodrie, LA, where they were subjected to a quarantine period of no less than one month. During quarantine, fish were treated with copper sulfate and praziquantel to eradicate naturally-occurring parasites. Copper sulfate is effective at eliminating virulent gill parasites such as *Amyloodinium* spp. and exposure to praziquantel eliminates monogenetic trematodes. Pompano were fed via automatic feeders during the quarantine period. After quarantine was completed, approximately 400 fish were transported to the Aquaculture Research Station (ARS), Baton Rouge, LA in late December 2000. At the ARS, the fish were subjected to a two-week acclimation period in a closed recirculating system before experiments were initiated. Feed ration sizes to be used in subsequent experiments were determined during the acclimation period.

Four, indoor, closed recirculating systems were used in the experiment. Two of the systems (E and F) each consisted of eight, 350-L circular tanks, equipped with a bead filter, a ¼ horsepower pump, and a 40-watt ultraviolet (UV) disinfection unit. Flow-rate into each tank was approximately 12-L/minute. The remaining two systems (LB and FM) each consisted of four 1,500-L circular tanks equipped with a bead filter, a ¼ horsepower pump, and a 40-watt UV disinfection unit. Flow-rate into each tank was approximately 30-L/minute. The two smaller systems were used while the fish weighed less than 250 g (Experiments 1 and 2). The larger systems were used during Experiment 3. Aeration was provided to all systems via airstones supplied by a low-pressure blower. Nylon nets (0.6-cm mesh) were placed over each tank to prevent fish from jumping out.

Marine recirculating bead filters (MRBF) were used in this study. These filters contained a bed of floating plastic beads that served to collect waste and as media for nitrifying bacteria. The units used in this study are designed to provide complete biofiltration and solids capture for up to 2.7 kg of feed per day (Beecher et al. 1997, Sastry et al. 1999). The MRBF are especially suitable for marine systems because they lose very little water during sludge removal. In this present study, filters used with the smaller systems (E and F) contained a 0.05-m^3 floating bead bed, while filters used with the larger systems (LB and FM) contained a 0.1-m^3 floating bead bed.

Filter acclimation was conducted as described by Manthe and Malone (1987). Ammonium chloride and sodium nitrite were each added to systems in initial doses of 5 mg/L. Filters were seeded with commercial additives containing nitrifying bacteria and sludge from established systems. When ammonium levels began to decrease, ammonia chloride was added in daily doses of 5 mg/L.

Salinity was maintained between 23 and 28 g/L throughout the experiments with the use of synthetic sea salts. Two heating units maintained ambient air temperature between 25 and 30 C. Water temperature ranged from 27 to 29 C. Water temperature, dissolved oxygen, and salinity were measured daily throughout the experiments with a YSI 85 meter (YSI Inc., Yellow Springs, OH). Dissolved oxygen levels were maintained above 5 mg/L. A 12:12 photoperiod was provided with overhead fluorescent lights controlled by electric timers. Water quality parameters, including total ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, alkalinity, pH, and dissolved oxygen were measured every other day. Total ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, and alkalinity were measured using Hach test kits (Hach Co., Loveland, CO). An ORION electric pH meter (model 330 ORION Research, Inc., Boston, MA) was used to measure pH. Ammonia-nitrogen, nitrite-nitrogen, and nitrate-nitrogen levels were maintained at levels below 0.3, 0.1, and 45-50 mg/L, respectively. Alkalinity and pH were maintained at approximately 200 mg/L and 8.0, respectively. Sodium bicarbonate was added to the systems to increase alkalinity and balance pH as described by Loyless and Malone (1997).

One of the large rearing systems was constructed along an outside wall containing a bank of windows. To reduce variability between the two large systems due to direct sunlight (e.g., increased temperature, algal growth), heavy shade-cloth was placed over the bank of windows to prohibit sunlight from penetrating into this system. Manual backwashing of bead filters was performed every 3 to 4 hours during daylight hours. Sludge was removed from each filter every other day. Fish were fed a 53%-protein, 13%-lipid diet (Burris Mill and Feed, Franklinton, LA). A #3 crumble was used for Experiments 1 and 2, and during the first 15 days of Experiment 3. A 0.5-cm pellet was fed for the remainder of Experiment 3.

Fish were fed sparingly during the first week of the acclimation period. Maximum feed intake at one feeding was determined during the second week of the acclimation period. In Experiment 1, initial maximum daily rations were determined based on the amount of feed consumed in one 30-minute feeding. Fish received as much feed as they could consume in 30 minutes. The amount of feed provided to each tank was compared to the tank biomass to estimate feeding rate as a percentage of body weight. It was determined during the acclimation period that the fish (mean weight, 15 g) consumed 5% of body weight per day.

Production characteristics (mean weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), and survival were determined for each experiment. SGR was calculated using the formula: $[\ln(w_t) - \ln(w_i)]/t * 100$, where w_t = weight at the end of a sampling period, w_i = initial weight and t = length of time of the sampling period in days (Watanabe et al. 2001). FCE was calculated using the formula: (g weight gain/g feed) *100 (Lazo et al. 1998).

CHAPTER 3
EXPERIMENT 1 – EFFECTS OF FEEDING FREQUENCY ON GROWTH OF JUVENILE POMPANO (17-61 G)

Methods

After the acclimation period, fish were hand-graded to reduce size variability. Eighteen fish (mean individual weight, 17 g) were stocked into each 350-L tank (0.9 kg/m^3). Fish were weighed individually to the nearest 0.01 g using a Denver Instrument model XL-1810 electric scale (Denver Instrument Co., Arvada, CO) prior to stocking.

The experiment was initiated on January 29, 2001. Fish were fed daily rations (5% of body weight) in one, two, three, or six feedings per day (Table 1). The amount required for each daily feeding was determined during the prior acclimation period. Using the mean initial weight, a feed ration equivalent to 5% of body weight was calculated for each tank of fish. Treatments were assigned to two tanks of fish in each system in a randomized complete block design with four replicates per treatment.

Every two weeks, fish were counted and individually weighed to determine production characteristics for each treatment. Mean weight of fish from each treatment was used to recalculate appropriate feed rations for the next two weeks. Rations for each tank were adjusted for mortalities when necessary. When the mean weight of all fish increased by at least 300%, the study was terminated and final production characteristics were determined.

A parasitic gill infection (*Trichodina* spp.) was detected 12 days after treatments began. Infestations of *Trichodina* do not typically cause high mortalities, but can cause losses at very high concentrations (Dr. John Hawke, personal communication). Subsequently, copper sulfate was added to the systems at a concentration of 0.2 ppm (as Cu). These concentrations were maintained for the duration of the experiment to determine the efficacy of the copper sulfate

TABLE 1. Daily feeding schedule.

	Feedings per day			
Time	**Six**[1]	**Three**[2]	**Two**[3]	**One**[4]
900	**x**	**x**	**x**	
1000				
1100	**x**			
1200				
1300	**x**	**x**		**x**
1400				
1500	**x**			
1600				
1700	**x**			
1800				
1900	**x**	**x**	**x**	

[1]Tanks E2, E6, F4, F8
[2]Tanks E3, E5, F1, F7
[3]Tanks E4, E7, F2, F6
[4]Tanks E1, E8, F3, F5

treatment. Weekly gill clippings were obtained from randomly selected fish to monitor parasite loads. Fish used to obtain gill clippings were placed back, unharmed, into the appropriate tank.

The experiment was terminated on March 8, 2001 after 38 days. It was determined after the second sampling date (29 days) that another full sampling period would not be needed to reach the predetermined growth increase of 300%. One fish from each treatment was randomly collected and frozen at –80 C for analysis of body composition. All chemical analyses were conducted in triplicate. Frozen samples were thawed at room temperature and dried to a constant weight in a 100 C oven. Dry samples were used to measure protein, lipid, and ash content. Protein content was determined using the Kjeldahl method. Lipid content was determined by chloroform extraction. Dry samples were burned at 600 C in a muffle furnace to determine ash content. Feed used in this study also was analyzed using the same protocol.

Statistical analyses were performed using statistical analysis software (SAS version 8.1, Carey, North Carolina). All data were subjected to analysis of variance (ANOVA) and means separation was achieved using Tukey's studentized range test at a significance level of $\alpha = 0.05$.

Results

After 38 days, mean weight of pompano across treatment groups was 61.5 g. Significant differences in mean weight and weight gain occurred only at the final sampling date. At the conclusion of the experiment, mean weight of fish fed two (64.5 g) and six (64.2 g) times per day was greater ($P \leq 0.05$) than fish fed once per day (56.2 g) (Table 2). Mean weight of fish fed three times per day (62.0 g) did not differ significantly from mean weight of fish in any of the remaining treatments (Table 2). Overall weight gain of fish fed twice per day (47.5 g) was greater ($P \leq 0.05$) than that of fish fed once per day (39.3 g) (Table 3). However, weight gain of fish fed three (45.9 g) or six (46.9 g) times per day did not differ significantly from each other or

TABLE 2. Weight (means ± standard error) in grams of pompano during Experiment 1. Values in each row with different letters are significantly different.

	Feeding Frequency (Times per Day)			
Day	**1**	**2**	**3**	**6**
1	17.04	17.04	17.04	17.04
14	28.0 ± 1.0	29.6 ± 1.0	28.8 ± 0.9	30.2 ± 1.1
29	44.2 ± 1.7	48.7 ±1.7	47.4 ± 1.4	48.6 ± 1.7
38	56.2 ± 2.2^{b}	64.5 ± 2.0^{a}	62.0 ± 1.9^{ab}	64.2 ± 2.3^{a}

TABLE 3. Weight gain, feed conversion efficiency (FCE), and specific growth rate (SGR) (means ± standard error) of pompano (mean initial weight, 17 g) during Experiment 1. Fish were fed a fixed ration (5% bw/day) at one of four frequencies. Values in each column with different letters are significantly different.

		Days of Treatment			
Parameter	**Feeding Frequency**	**1-14**	**15-29**	**30-38**	**1-38**
Weight gain (g)	1	11.1 ± 1.2	16.2 ± 1.9	12.0 ± 2.9	39.3 ± 2.4[b]
	2	12.2 ± 1.2	19.3 ± 1.9	15.7 ± 2.7	47.5 ± 2.0[a]
	3	12.5 ± 1.0	18.6 ± 1.6	14.4 ± 2.6	45.9 ± 2.1[ab]
	6	12.8 ± 1.2	18.5 ± 2.2	15.6 ± 2.8	46.9 ± 2.2[ab]
FCE (%)	1	67.5 ± 3.6	67.0 ± 2.4	56.9 ± 1.9	63.6 ± 2.4
	2	80.2 ± 2.8	72.8 ± 2.9	68.2 ± 6.0	73.1 ± 3.7
	3	72.6 ± 6.6	75.0 ± 4.2	62.4 ± 5.9	70.2 ± 3.7
	6	81.2 ± 4.1	71.2 ± 2.1	75.0 ± 6.0	74.9 ± 3.1
SGR (%/d)	1	3.6 ± 0.2	3.1 ± 0.4	2.6 ± 0.7	3.1 ± 0.2
	2	3.8 ± 0.4	3.3 ± 0.4	3.2 ± 0.6	3.5 ± 0.1
	3	4.2 ± 0.3	3.3 ± 0.3	2.9 ± 0.6	3.6 ± 0.1
	6	3.9 ± 0.4	3.2 ± 0.4	3.0 ± 0.7	3.4 ± 0.1

from weight gain of fish fed once or twice per day (Table 3).

No significant differences in FCE, SGR, or survival were detected at any of the sampling dates. However, fish fed once per day had numerically lower FCE and SGR than fish fed 2, 3, or 6 times per day (Table 3). On the first sampling date (14 days), FCE ranged from 67.5 to 81.2%. On the 38th day, FCE ranged from 63.6 to 74.9%. SGRs tended to decline among all four treatment groups as the study progressed, but reductions were not statistically significant. SGR on the 14th day ranged from 3.6 to 4.2%/day. SGR ranged from 2.6 to 3.2%/day during the final 10 days of the experiment. Survival was over 95% in all treatment groups (Figure 1). No significant differences in whole body composition were observed among treatment groups (Table 4).

Discussion

Fish acclimated to the experimental systems readily and survival was excellent. The majority of mortalities were due to the *Trichodina* outbreak. Fish accepted feed within hours after they were placed in the culture systems.

Significant differences in mean weight and weight gain did not occur until the final sampling date. There appear to be different reasons why fish fed two and six times per day exhibited better growth than fish fed once per day. Feeding activity of wild and captive pompano has been shown to peak in the morning hours and decrease as the day progresses (Heilman and Spieler 1999, Modde and Ross 1983). It has been suggested that, because pompano do not appear to feed at night, increased feed intake in the morning hours serves to replenish metabolic energy expended during the night (Heilman and Spieler 1999). Pompano also have been shown to exhibit increased growth when fed later in the day (Heilman and Spieler 1999). Among fish fed twice per day in this study, it is possible that feed consumed in the

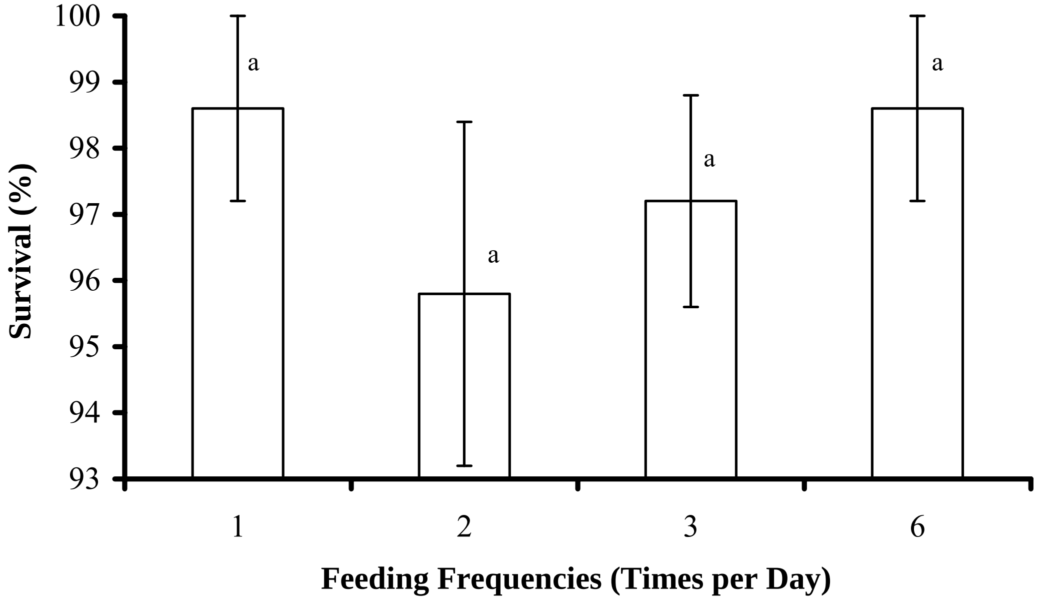

FIGURE 1. Survival (means ± standard error) of pompano (mean initial weight, 17 g) reared in closed recirculating systems. Fish were fed a fixed ration (5% bw/day) at one of four frequencies for 38 days. There were no significant differences in survival among treatments.

TABLE 4. Whole body composition of pompano (mean weight, 61.5 g) fed a fixed ration (5% bw/day) at one of four frequencies. Values are means. Protein, lipid, and ash percentages are expressed on a dry weight basis. Means in each row are not significantly different.

	Feeding Frequency (Times Per Day)			
	1	**2**	**3**	**6**
Dry Matter (%)	35.05	33.64	32.65	33.69
Crude Protein (%)	49.00	49.36	50.65	51.28
Lipid (%)	43.95	39.94	44.52	41.78
Ash (%)	9.43	8.98	10.22	9.47

morning hours was sufficient to replenish depleted energy and promote growth. Feed consumed in the afternoon may have been channeled primarily toward growth, as suggested by Heilman and Spieler (1999).

Six feedings per day may have been most efficient for the digestive system of pompano. Although mean weight and weight gain of fish fed two and six times per day did not differ in the present study, numerous multiple feedings have been shown to be beneficial in several other finfish species. Sockeye salmon (*Oncorhyncus nerka*) exhibited better growth when fed continuously for 15 h/day, compared to a limited number of feedings to-satiation per day (Shelbourne et al. 1973). Rainbow trout fed a fixed amount of diet with an automatic (continuous) feeder exhibited better weight gain than trout fed the same ration divided into four feedings (Hung and Storebakken 1994). It also has been shown that growth of red-spotted grouper (*Epinephelus akaara*) was enhanced at frequencies of 4 to 6 feedings per day (Kayano et al. 1993).

Like most carnivorous fishes, pompano have a relatively short digestive tract. Feed transit time through the gut has been estimated at approximately 3 hours (Williams et al. 1985). It has been suggested that a single, large intake of food may increase the rate of movement of food through the digestive system and therefore reduce digestion efficiency (Lazo et al. 1998).

Mean weight and weight gain of pompano that received three feedings per day did not differ significantly from those of fish in other treatment groups, although these fish occasionally exhibited numerically-higher FCE and SGR. Elevated (but not statistically significant) FCEs and SGRs were observed for fish fed two, three, or six times per day. Fish fed once per day exhibited the lowest FCE and SGR. Fish fed three times per day appeared to share many of the same growth traits associated with fish fed twice per day. The lack of significant differences in

FCE and SGR between treatment groups was likely due to high variability in these parameters among individual fish. It is possible that larger, faster-growing fish consumed most of the feed offered. Because the ration size was limited, larger fish might not have become satiated and might have consumed a larger portion of the feed than smaller, slower-growing fish.

Increased FCE associated with multiple feedings has been reported in other studies. Rainbow trout that received a fixed ration in a continuous 24-h feeding exhibited higher FCE than trout fed the same ration in four feedings (Hung and Storebakken 1994). Red-spotted grouper also exhibited higher FCE when fed a fixed ration in multiple feedings (Kayano 1993). Increased feeding frequencies give fish more opportunities to consume and digest feed throughout the day. Pompano fed once per day might digest feed for 3 hours per day, while pompano fed six times per day might digest feed for 18 hours per day. Longer periods of digestion increase the efficiency of digestion and nutrient assimilation.

FCEs observed in the present study (63 to 81%) are greater than those reported from other studies with pompano. Tatum (1972) reported an FCE of 30% for pompano fed a commercial trout chow. Pompano fed diets with higher protein and lipid levels than found in typical commercial trout or catfish feeds have exhibited higher FCE. Juvenile pompano fed diets composed of 12% lipid and 42% protein (Williams et al. 1985), or 8% lipid and 45% protein (Lazo et al. 1998) exhibited FCE values of 44% and 51%, respectively. The high FCE observed in the present study may have been due to the higher lipid (13%) and protein (53%) composition of the feed used, compared with feeds used in other studies. However, FCE values obtained in the present study are well below those reported in studies conducted with some other marine fishes. For example, FCE values of red drum (*Sciaenops ocellatus*) have been reported to range from 82 to 98% (Serrano et al. 1992).

It has been suggested that increased feeding frequency can increase accretion of dietary protein in muscle (Kayano et al. 1993). No patterns between feeding frequency and proximate body composition were apparent in this study. However, whole-body lipid levels were noticeably higher than those reported for juvenile pompano in other studies. Lipid levels between 18.5 and 21.6% (dry weight basis) have been reported in juvenile pompano (mean weight, 25 g) (Lazo et al. 1998). Whole body lipid levels between 39.9 and 44.5% (dry weight basis) were obtained in the present study. This suggests that the energy content of the diet was in excess of the requirements of pompano raised in a recirculating system of the type used in this study. It is possible that a diet containing 53% protein and 13% lipid is more than pompano require for maximum growth and digestion efficiency under the culture conditions reported here.

Results indicate that juvenile pompano require only two feedings per day under the conditions reported in this experiment. Fish fed twice per day had the greatest mean weight gain and the highest final body weight. The highest FCEs and SGRs also were observed for fish fed multiple times per day. While results from six and two feedings per day were similar, feeding fish twice per day would require less labor. It is also possible that growth of fish in this study also might have been increased if a larger feed pellet had been used. A #2 crumble was used for the duration of the study. It is likely that the pompano could have consumed a larger crumble or a small pellet as they increased in size.

CHAPTER 4
EXPERIMENT 2 - EFFECTS OF FEEDING RATE AND STOCKING DENSITY ON GROWTH OF POMPANO (74-200 G)

Methods

Experiment 2 was initiated on March 16, 2001. Pompano used in Experiment 1 were hand-graded to reduce size variability. Fish (mean individual weight, 74 g) were stocked into each 350-L tank at densities of approximately 1.3 kg/m^3 (6 fish) or 2.6 kg/m^3 (12 fish). Fish were fed twice per day (the optimal feeding frequency determined in Experiment 1) at either a fixed rate or to apparent satiation. Feedings occurred at 0900 and 1500 hours. Fish fed to satiation were allowed to consume as much feed as they would eat in 30 minutes. Fish fed the fixed rate received 5% of body weight per day. Each density and feeding rate treatment was assigned to tanks in a randomized complete block design with four replicates per treatment (two tanks per system).

Every two weeks, fish in each tank were counted and individually weighed to determine production characteristics of each treatment group. Mean weight of the fixed-rate treatment groups was used to adjust feed rations for the next two weeks. Feed rations for each tank were adjusted for mortalities when necessary.

The copper sulfate treatment employed in Experiment 1 had no apparent effect on the infestation of *Trichodina* spp. Formalin (37%) baths were used as an alternative treatment for these parasites. To reduce levels of this gill parasite, on each sampling date fish were treated with 150 mg/L formalin via a one-hour bath treatment prior to being returned to their tanks. Treatment occurred in 140-L insulated containers. Fish were treated after weighing to reduce handling stress. Formalin treatments effectively removed gill parasites, however, because parasites remained in the rearing systems, bath treatments were necessary on each sampling date for the duration of the study. Weekly gill clippings to monitor parasite concentrations were continued as described in Experiment 1.

Experiment 2 was terminated prematurely on May 9, 2001 because of increased parasite loads in both systems. Mean weight of fish across treatment groups after 54 days was 200.5 g Mean weight of fish across treatment groups had increased 290% at the time the experiment was terminated; slightly below that of the desired 300% increase in body weight. One fish from each tank was randomly collected and frozen at –80 C for analysis of body composition as described in Experiment 1. Production characteristics were determined and statistical analyses were performed as described in Experiment 1.

Results

Significant differences in mean weight were detected at all sampling dates (Table 5). At the first sampling date (14 days), mean weight (122.6 g) of fish fed to satiation and initially stocked at a density of 2.6 kg/m^3 was greater ($P \leq 0.05$) than that of fish fed at the fixed rate and stocked at the same density (108.6 g) or a density of 1.3 kg/m^3 (104.5 g). Mean weight of fish (118.2 g) stocked at a density of 1.3 kg/m^3 and fed to satiation was significantly greater than that of fish fed at a fixed rate. At the second (28 days), third (43 days), and fourth (54 days) sampling dates mean weight of fish fed to satiation and stocked at either density was higher ($P \leq 0.05$) than that of fish fed at a fixed rate and stocked at a density of 1.3 kg/m^3. Mean weight of fish fed a fixed ration and stocked at a density of 2.6 kg/m^3 did not differ significantly from that of fish fed to satiation at either density.

Significant differences in weight gain were detected at the first sampling date and after 54 days (Table 6). Weight gain of fish fed to satiation and stocked at a density of 2.6 kg/m^3 (48.7 g) was greater ($P \leq 0.05$) than that of fish fed at the fixed rate and stocked at a density of 2.6 kg/m^3

Table 5. Weight (means ± standard error) in grams of pompano during Experiment 2. Fish were stocked at one of two densities and fed twice per day, either a fixed ration (5% bw/day) or to apparent satiation. Values in each row with different letters are significantly different.

	Fixed		**Satiation**	
Day	**1.3 kg/m^3**	**2.6 kg/m^3**	**1.3 kg/m^3**	**2.6 kg/m^3**
0	73.9	73.9	73.9	73.9
14	104.5±2.2^{c}	108.6±2.1^{cb}	118.2±3.4^{ab}	122.6±2.8^{a}
28	136.1±3.5^{b}	144.4±3.5^{ab}	157.1±5.5^{a}	160.6±4.2^{a}
43	167.3±4.9^{b}	181.4±5.4^{ab}	197.7±6.9^{a}	198.7±6.2^{a}
54	181.0±6.1^{b}	194.3±6.1^{ab}	213.6±7.6^{a}	213.2±7.1^{a}

TABLE 6. Weight gain, feed conversion efficiency (FCE), and specific growth rate (SGR) (means ± standard error) of pompano (mean initial weight, 73.9 g) during Experiment 2. Fish were stocked at one of two densities and fed twice per day, either a fixed ration (5% bw/day) or to apparent satiation. Values in each column with different letters are significantly different.

		Days of Treatment				
Parameter	**Treatment**	**1-14**	**15-28**	**29-43**	**44-54**	**1-54**
	$1.3\ kg/m^3$ - Fixed	30.6 ± 2.2[c]	31.5 ± 4.1	31.2 ± 5.6	13.7 ± 7.0	107.1 ± 6.1[b]
	$2.6\ kg/m^3$ - Fixed	34.7 ± 2.1[cb]	35.8 ± 4.2	37.0 ± 6.7	13.9 ± 8.4	120.4 ± 6.1[ab]
Weight gain (g)	$1.3\ kg/m^3$ - Satiation	4.3 ± 3.4[ab]	38.9 ± 4.1	40.5 ± 9.1	16.0 ± 8.5	139.7 ± 7.6[a]
	$2.6\ kg/m^3$ - Satiation	48.7 ± 2.8[a]	38.1 ± 5.7	38.0 ± 7.9	13.3 ± 9.9	139.3 ± 7.1[a]
	$1.3\ kg/m^3$ - Fixed	56.9 ± 4.9	44.0 ± 1.3	36.2 ± 3.7	19.2 ± 1.2	37.8 ± 1.7
	$2.6\ kg/m^3$ - Fixed	60.1 ± 6.2	48.3 ± 1.4	38.0 ± 1.2	11.2 ± 3.9	37.6 ± 1.0
FCE (%)	$1.3\ kg/m^3$ - Satiation	60.0 ± 2.4	42.4 ± 2.4	40.7 ± 1.8	17.0 ± 2.5	38.8 ± 1.3
	$2.6\ kg/m^3$ - Satiation	63.5 ± 1.6	43.7 ± 2.6	40.2 ± 2.7	13.3 ± 3.5	40.3 ± 2.1
	$1.3\ kg/m^3$ - Fixed	2.58±0.2b	1.86±0.2	1.36±0.2	0.63±0.4	1.64±0.1
	$2.6\ kg/m^3$ - Fixed	2.71±0.2b	1.99±0.2	1.46±0.3	0.60±0.4	1.72±0.1
SGR (%/d)	$1.3\ kg/m^3$ - Satiation	3.31±0.2ab	2.00±0.2	1.51±0.4	0.65±0.4	1.91±0.1
	$2.6\ kg/m^3$ - Satiation	3.56±0.2a	1.88±0.3	1.38±0.3	0.52±0.4	1.89±0.1

(34.7 g) or 1.3 kg/m^3 (30.6 g). Fish fed to satiation and stocked at a density of 2.6 kg/m^3 exhibited significantly greater weight gain (44.3 g) than fish fed at a fixed rate and stocked at a density of 1.3 kg/m^3. Weight gain of fish fed to satiation at either density (139.3 g and 139.7 g at densities of 2.6 and 1.3 kg/m^3, respectively) was greater ($P \leq 0.05$) after 54 days than that of fish fed at a fixed rate and reared at a density of 1.3 kg/m^3 (107.1 g). Weight gain of fish fed the fixed rate and stocked at a density of 2.6 kg/m^3 (120.4 g) was not significantly different after 54 days than that of fish in the other treatment groups. No significant differences in weight gain among treatment groups was detected during the final three sampling periods of Experiment 2.

Significant differences were detected in SGR only during the first sampling period (Table 6). FCE (Table 6) and survival (Figure 2) did not differ ($P > 0.05$) among treatment groups at any time during the experiment. However, FCE and SGR steadily decreased as the study progressed. After 14 days, SGR of fish fed to satiation and stocked at a density of 2.6 kg/m^3 (3.56%/day) was greater ($P \leq 0.05$) than that of fish fed at a fixed rate and stocked at a density of 1.3 kg/m^3 (2.58%/day) or 2.6 kg/m^3 (2.71%/day). Fish fed to satiation and stocked at a density of 1.3 kg/m^3 exhibited an SGR (3.31%/day) after 14 days that was not significantly different from that of fish in the other treatments. During the final sampling period (days 44-54), SGR ranged from 0.52 to 0.65%/day. At the first sampling date, FCE ranged from 56.9 to 63.5%. During the final sampling period (days 44-54), FCE ranged from 11.2 to 19.2%. Survival in all four treatment groups was greater than 95% (Figure 2). No significant differences in body composition were detected among treatments (Table 7).

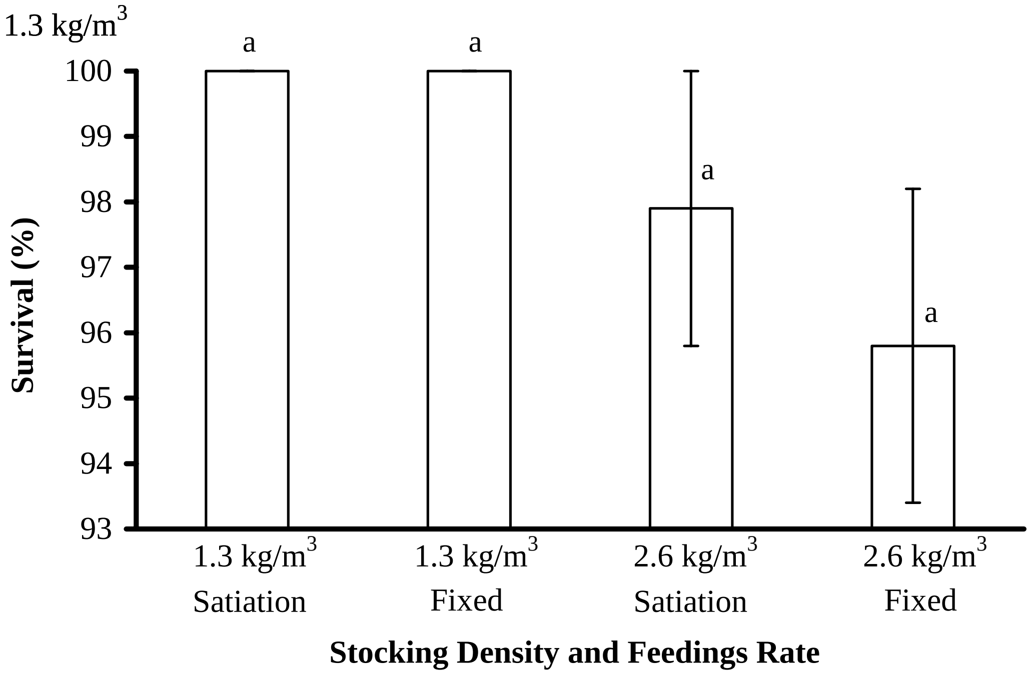

FIGURE 2. Survival (means ± standard error) of pompano (mean initial weight, 74 g) raised in closed recirculating systems for 54 days. Fish were stocked at one of two densities and fed twice per day, either a fixed ration (5% bw/day) or to apparent satiation. Survival did not differ significantly among treatments.

TABLE 7. Whole body composition of pompano (mean weight, 200.5 g) at termination of Experiment 2. Fish were stocked at one of two densities and fed twice per day, either a fixed ration (5% bw/day) or to apparent satiation. Values are means. Percentages are expressed on a dry weight basis. No significant differences were detected among treatments.

	Fixed		**Satiation**	
	1.3 kg/m^3	**2.6 kg/m^3**	**1.3 kg/m^3**	**2.6 kg/m^3**
Dry Matter (%)	34.45	36.41	35.70	35.46
Crude Protein (%)	48.53	46.47	48.60	46.87
Lipid (%)	43.19	46.00	39.89	46.02
Ash (%)	8.27	8.29	7.73	8.32

Discussion

At each sampling period, increased differences in daily feed intake developed between fish fed to satiation and those fed at a fixed rate. Fish fed to apparent satiation were allowed to maximize food intake at each feeding. Fish were able to increase consumption as body weight increased. In contrast, fish that received the restricted ration were allowed only the amount of feed that was determined at the onset of each sampling period. Because the fixed ration (5% bw/day) was based on the weight of fish at the end of the previous sampling period, fish consumed an increasingly lower percentage of body weight as time progressed.

Growth of many fishes increases with increasing ration size (Brett 1979). This occurred in the present study, where fish fed to satiation had better initial growth compared to fish that received restricted feedings. Similar results were observed in a study conducted with two size ranges of Atlantic Sturgeon (*Acipenser oxyrinchus*); the greatest growth in both size classes occurred among fish that received the largest ration size (Kelly and Arnold 1999). During the fall and winter, chinook salmon (*Oncorhynchus tshawytscha*) fed to satiation achieved higher mean weight than salmon fed at a level of 67% of satiation (Mazur et al. 1993).

Feeding rate did not appear to have a significant effect on digestion efficiency of pompano fed twice per day, because FCE did not vary among treatment groups in the present study. Since feed was offered in two feedings per day, and at the same time of day in all treatments, it is likely fish digested feed for similar periods of time each day. In a study conducted with chinook salmon, FCE of fish fed to satiation was generally lower than FCE of fish fed at a level of 67% of satiation (Mazur et al. 1993).

As reported in previous studies conducted with pompano, FCE decreased greatly as fish approached and surpassed a size of 150-200 g. In the present study, FCEs (63.5-36.2%) during the first three sampling periods (days 1-43) were higher than those previously reported. McMaster (1988) reported that FCE of pompano (150-200 g) ranged from 28.5% to 16%. An FCE of 22.5% for pompano of the same size range harvested at densities between 17.9 and 115 kg/$m^3$was reported by Smith (1973). FCE of 31-51% (Lazo et al. 1998) and 44% (Williams et al. 1985) have been reported for pompano weighing much less (5-30 g body weight) than fish in the present study. However, in the present study, during the period when the fish grew from mean weights of 187 g to 201 g (day 44-day 54), FCE fell below 20%.

FCE at 54 days ranged from 37.6-40.3%. It is possible that reduced growth and low FCE observed near the conclusion of the present study could have been caused by stressful environmental conditions. For example, the high concentrations of parasites within rearing systems could have caused stress that reduced growth.

It has been suggested that stocking 100-g pompano at densities lower than 60 kg/m^3 might promote more efficient growth (McMaster 1988). Because pompano are such active fish, high stocking rates may reduce growth by increasing behavioral interactions. However, since densities at termination of the present study were 3.4 and 6.8 kg/m^3, it is possible that crowding was not a factor that affected growth in this study.

The stocking densities used in this study had no effect on growth of pompano. It is possible that densities were similar enough not to produce significant differences. The number of available fish was a limiting factor in determining stocking densities. It is important to note that stocking density used in the present study was lower than what commercial producers would probably consider necessary to be profitable.

No differences with respect to body composition among treatment groups were evident. As noted in Experiment 1, lipid levels were unusually high in all treatment groups, ranging between 39.9 and 46.0% (dry weight). These levels are much higher than those reported by Williams et al. (1985) and Lazo et al. (1998). Again, this may indicate that the feed used in this study contained excessive energy for pompano raised under the conditions reported here.

Results of Experiment 2 indicate that pompano exhibit maximum growth when fed to satiation rather than when fed a fixed diet at 5% body weight per day. Because no significant differences with respect to production characteristics or body composition were observed among stocking densities evaluated in this study, no specific recommendation regarding stocking density can be made. However, both stocking densities may have been in the range suitable for optimal growth. A drastic decline in FCE occurred as the fish approached 200 g in size. This could have been caused by a stress response related to the level of parasites in the system, although this could not be determined definitively. Additional research is needed to determine optimal stocking densities for pompano of this size.

CHAPTER 5
EXPERIMENT 3 – EFFECTS OF FEEDING FREQUENCY ON GROWTH OF LARGE POMPANO (215-723 G)

Methods

Experiment 3 was initiated on May 11, 2001. Fish from Experiment 2 were hand-graded to reduce size variability. All fish used in the study were subjected to a 150 mg/L formalin bath prior to stocking as described previously. All fish were individually weighed to the nearest 0.5 g on an A & D electronic balance, model EP-40KA (A & D Co., Tokyo, Japan). Eleven fish (mean individual weight, 215 g) were stocked into each of eight, 1,500-L tanks (density = 1.6 kg/m^3). The stocking rate was determined by the number of available fish in the suitable size range. Fish were fed to apparent satiation two or four times per day. Feedings occurred at 0900, 1230, 1530, and 1900 hours. Fish that received two feedings per day were fed at 0900 and 1900 hours. At each feeding, fish received as much feed as they would consume in 30 minutes. Feeding frequencies were assigned to two tanks in each system in a randomized complete block design with four replicates per treatment.

Every 3 weeks all fish were counted and individually weighed until all the fish reached market size (~450 g). Formalin bath treatments to control parasites continued throughout the experiment at each sampling date. Gill clippings of randomly selected fish were obtained on a bi-weekly basis for the duration of the study.

Samples of fish were obtained for analysis of body composition on July 13, 2001, when the mean weight of fish in all treatment groups reached a size of no less than 450 g. At this time, one fish from each tank was randomly collected and frozen at –80 C. Another fish was randomly chosen from each tank to determine production characteristics (dressed carcass yield, fillet yield, hepatosomatic index, and visceral fat content). The head and internal organs were removed to determine the dressed carcass yield. Livers were removed and weighed for hepatosomatic indices. Fillets were manually removed from the dressed carcass to determine the fillet yield. Fat was removed from the visceral cavity to determine visceral fat content.

Measurement and statistical analysis of production characteristics were performed as described in Chapters 3 and 4. After samples were obtained for analysis of body composition and production characteristics, remaining fish continued to be subjected to experimental treatments until the mean weight of fish in all treatments had increased by at least 300%. Sampling of these post-market size fish occurred at approximately four-week intervals. The experiment was terminated on September 21, 2001 with subsequent measurement and analysis of production characteristics.

Results

Mean weight of pompano after 63 days was 527.2 g. Significant differences were detected in mean weight and weight gain at various stages of Experiment 3 (Figure 3). Mean weight of fish at the first (21 days) and second (42 days) sampling dates was higher ($P \leq 0.05$) among fish fed four times per day (309.8 g and 449.7 g, respectively) than among fish fed twice per day (288.2 g and 420.0 g, respectively). Mean weight of fish fed four (449.7 g) or two (420.0 g) times per day was not significantly different on the third sampling date (63 days). Weight gain of fish fed four times per day (91.2 g) was higher ($P \leq 0.05$) at the first sampling period than that of fish fed twice per day (69.6 g) (Table 8). Weight gain of pompano during the second through fifth sampling periods was not significantly different between treatment groups. However, final weight gain of fish fed four times per day (535.4 g) was higher ($P \leq 0.05$) than that of fish fed twice per day (472.9 g) (Table 8).

No significant differences in FCE existed between treatment groups throughout the

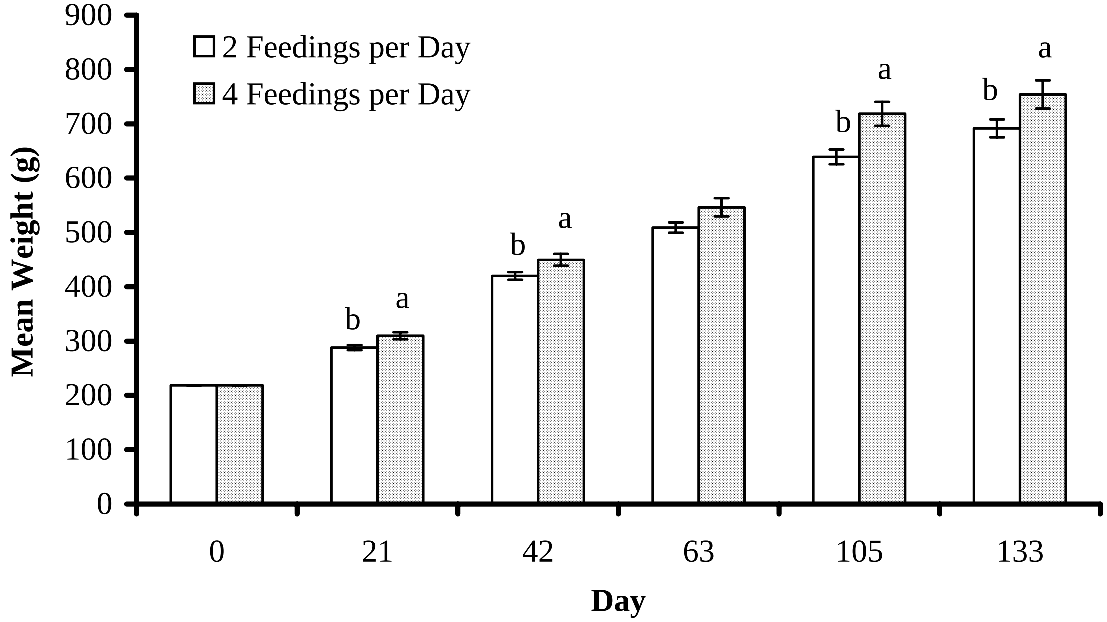

FIGURE 3. Weight (means ± standard error) of pompano during Experiment 3. Fish were fed to apparent satiation two or four times per day. Bars with different letters at each day are significantly different.

TABLE 8. Weight gain, feed conversion efficiency (FCE) and specific growth rate (SGR) (means ± standard error) of pompano (mean initial weight, 215 g) during Experiment 3. Fish were fed to apparent satiation either two or four times per day. Values in each column with different letters are significantly different.

		Days of Treatment					
Parameter	**Feeding Frequency**	**1-21**	**22-42**	**43-63**	**64-105**	**106-133**	**0-133**
Weight gain (g)	2	69.6 ± 4.6[b]	131.0 ± 7.8	88.9 ± 10.9	128.6 ± 15.5	52.4 ± 0.7	472.9 ± 16.4[b]
	4	91.2 ± 6.3[a]	138.1 ± 14.1	96.4 ± 18.2	179.8 ± 23.2	43.4 ± 26.3	535.4 ± 25.7[a]
FCE (%)	2	43.0 ± 2.9	45.4 ± 8.1	35.0 ± 2.3	1.2 ± 0.2	19.7 ± 2.0	24.4 ± 2.4
	4	44.6 ± 3.7	46.4 ± 2.3	27.8 ± 3.6	6.9 ± 0.8	4.9 ± 8.1	22.8 ± 2.3
SGR (%/d)	2	1.2 ± 0.2[b]	1.8 ± 0.2	0.9 ± 0.1	0.5 ± 0.1	0.3 ± 0.1	0.8 ± 0.2
	4	1.5 ± 0.2[a]	1.7 ± 0.2	0.8 ± 0.1	0.7 ± 0.1	0.2 ± 0.1	0.9 ± 0.2

experiment (Table 8). FCE tended to decrease as the study progressed. At 21 days, FCE ranged from 42.9 to 45.2%. At 63 days, FCE ranged from 37.9 to 41.3%. A significant difference in SGR occurred only at the first sampling period (Table 8). Specifically, after 21 days, SGR of fish fed four times per day (1.5%/day) was higher ($P \leq 0.05$) than that of fish fed two times per day (1.2%/day). After 63 days, SGR declined to 0.8%/day for fish fed four times per day and 0.9%/day for fish fed two times per day. Survival was greater than 93% (Figure 4) and was not significantly affected by experimental treatment.

Analysis of body composition yielded results similar to those obtained in the previous two experiments. In both treatments, body protein levels were greater than 40% of dry weight and lipid levels were greater than 47% of dry weight (Table 9). Ash levels ranged from 6-7%. There were no significant differences between treatment groups with respect to any measured component of body composition.

No significant differences in production characteristics were detected (Table 10). Fish of both treatment groups yielded dress-out percentages greater than 70% and fillet percentages greater than 45%. Visceral fat was virtually non-existent (0.1%). Hepatosomatic indices of fish from both treatment groups were greater than 1.2%.

Mean weight of fish after 133 days was 722.8 g. Mean weights at 105 days and 133 days were significantly higher among fish fed four times per day (718 and 754 g, respectively) than among fish fed two times per day (639 and 691 g, respectively) (Figure 3). No significant differences in weight gain of pompano among treatment groups were detected during the final two sampling dates (Table 8). However, fish fed four times per day gained more ($P \leq 0.05$) weight during the entire 133-day experiment than fish fed twice per day.

FCE and SGR also did not differ significantly at 105 or 133 days (Table 8). Values for

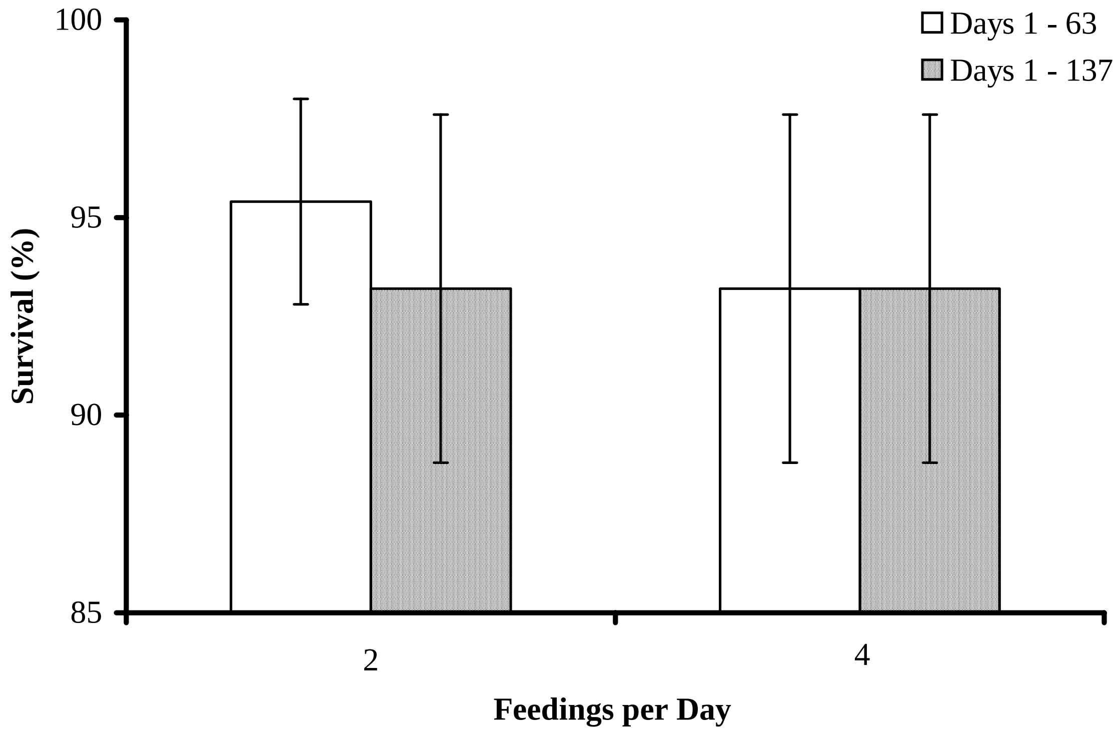

FIGURE 4. Survival (means ± standard error) of pompano (mean initial weight, 215 g) raised in closed recirculating systems. Fish were fed to apparent satiation either two or four times per day. Pompano reached market size (527.2 g) after 63 days. Mean weight after 133 days was 722.8 g. Survival did not differ significantly between treatments.

TABLE 9. Whole body composition of pompano (mean weight, 527.7 g) at termination of Experiment 3. Fish were fed to apparent satiation two or four times per day. Values are means. Percentages are expressed on a dry weight basis. There were no significant differences between feeding frequencies.

Feeding Frequency	Dry Matter (%)	Crude Protein (%)	Lipid (%)	Ash (%)
2	37.2	43.8	47.6	6.7
4	35.5	46.6	47.9	6.2

TABLE 10. Production characteristics of pompano (mean weight, 527.7 g) in Experiment 3. Values are means. There were no significant differences between treatments.

Feeding Frequency	Dressed Carcass Yield (%)	Fillet Yield (%)	Visceral Fat Content (%)	Hepatosomatic Index (%)
2	72.3	48.5	0.13	1.36
4	73.2	45.9	0.13	1.25

FCE and SGR declined during the feeding trial and were observed to be as low as 1.2 and 4.9% during the final two sampling periods. Mean FCEs were slightly above 20%. SGR decreased as low as 0.2 and 0.3%/day during the final sampling period. Mean SGRs were slightly less than 1%/day. Survival was 93% in both trials after 133 days (Figure 4).

Discussion

Survival in Experiment 3 was excellent. Mortalities occurred only from fish escaping (jumping) from tanks. Even with nylon netting covering the tanks, when startled, pompano sometimes managed to escape between the net and the tank.

Four feedings (to apparent satiation) per day was shown to increase growth of pompano in the present study. Fish fed four times per day had more opportunities during the day to consume feed. Increased opportunities to consume feed presumably allowed fish longer periods for digestion and nutrient assimilation. It is possible that fish fed four times per day were digesting feed twice as many hours per day as fish fed two times per day. Increased consumption and digestion could have supplied fish with more nutrients to support growth.

Even though weight gain was significantly different at only one sampling period, fish fed four times per day gained consistently more weight than fish fed twice per day. Variability in mean weight and weight gain increased as the study progressed and was generally higher for fish fed four feedings per day. It is possible that this variability was affected by the natural behavior of the fish. Feed was quickly consumed at each feeding. Large fish may have consumed more of the feed, leaving less for smaller fish.

Results of this study contrast with those of a similar study conducted with rainbow trout. Growth of rainbow trout was not affected when fish were fed to satiation one, three, or six times daily (Grayton and Beamish 1977). It has been suggested that fish growth increases with feeding frequency until some maximum frequency has been reached (Grayton and Beamish 1977). Red-spotted grouper show optimum growth when fed to satiation two or four times per day (Kayano et al. 1990). Optimal feeding frequencies may vary from species to species depending on swimming activity, age, and temperature. It is possible that pompano exhibit similar patterns. Four feedings to satiation per day may allow pompano to consume enough feed for maximum growth. Because four feedings was the highest frequency tested in the present study, it is impossible to determine if the optimal feeding frequency for pompano was reached. It is possible that pompano growth may be enhanced if fish are fed more than four times per day.

FCEs of fish reared to market size in the present study were higher than those reported in previous studies. As stated in Chapter 4, FCE of pompano ranging in size from 150-200 g have been reported to be between 16 and 22% (Smith 1973, McMaster 1988). However, FCE observed in the present study did not decline below 25% until fish exceeded 500 g in size. Over the 133-day experimental period mean FCE was 22.8% for fish fed four times per day and 24.4% for fish fed two times per day.

SGR decreased steadily as the study progressed. The declining SGR values observed as fish approached and surpassed 450 g in size corresponded with decreasing FCE. This decrease in FCE has been documented in virtually all other studies conducted with Florida pompano. In past studies, 200 g has been shown to be the average size when FCE begins to decline. In the present study, FCE did not decline greatly until the fish had attained market size ($\geq$ 450 g).

Analysis of body composition revealed the presence of moderate protein levels and high lipid levels. It appears that reductions in FCE and SGR were not related to the diet fed in the present study. It has been suggested that low FCE, SGR, and mean weight exhibited by fish reared at higher densities may be caused by stress related to increased behavioral interactions

(Mazur et al. 1993). Pompano are extremely active fish; they continuously swim at high speeds and are agitated very easily. Due to their natural swimming behavior, pompano may require lower stocking densities than other less-active fishes to avoid stressful conditions. Fish in this study were reared at relatively low stocking densities. On the final sampling date, densities were approximately 4 kg/m^3. It is possible this density was too low to be a major factor affecting growth of pompano of the size used in Experiment 3.

Results of the present study indicate that growth of Florida pompano increases with increased feeding frequency. Like other species, pompano may have a maximum feeding frequency which, when surpassed, no longer results in increased growth. This feeding frequency possibly is dependent on the maximum amount of feed the fish can consume. While pompano in this study attained better growth when fed four times per day, higher feeding frequencies may yield higher growth rates than were exhibited in this study. As stated in previous chapters, the excessively high lipid levels of fish in this study may signify that a 53%-protein, 13%-lipid diet contains more energy than Florida pompano require for optimal growth. Also, the stocking density used in this study, while efficient at rearing pompano to market size, may provide little or no profit to a commercial producer.

CHAPTER 6
SUMMARY AND CONCLUSIONS

While some previous studies and reports have suggested that Florida pompano hold promise as a commercially viable species, there has been limited success in attempts to culture this species. This study is the first report of pompano raised beyond the 200-g size barrier in closed systems. Results of this study demonstrate that Florida pompano can be grown from 17 g to market size in approximately 4.5 months in a closed, recirculating system. Excellent survival rates in all three experiments of the study revealed that pompano readily adapted to closed-system culture and were easily handled. High-energy diets, optimal environmental conditions, and efficient feeding strategies appear to be important in promoting rapid growth of pompano.

Wild pompano caught in the Gulf of Mexico reportedly average 211 g at one year of age (Nelson and Murphy 2001). Because the pompano used in the present study were collected during the late summer and early fall of 2000, it is likely that these fish reached an age of one-year in August or September of 2001. On September 21, 2001, the mean weight of all pompano that remained in this study was 712 g, approximately 340% larger than the average weight of one-year old wild pompano from the Gulf of Mexico.

Pompano in the present study exhibited better growth when fed to apparent satiation than when given a fixed ration of 5% of body weight per day. Fish fed to apparent satiation received approximately 8-9% of body weight per day. Pompano fed to satiation generally exhibited better growth characteristics with increased daily feedings. However, there is possibly a maximum daily feeding frequency beyond which pompano cease to exhibit increased growth. This peak was not determined during the present study. Fish fed a fixed amount (5% bw/day) exhibited the best production characteristics when fed twice per day.

The decreased FCEs of larger pompano that were reported in earlier studies also were exhibited by pompano in the present study. Previous reports indicated that this decline occurred when pompano reached sizes ranging from 150-200 g, about 50% of market size. Pompano in the present study did not exhibit this drop in feed efficiency until their mean weight had exceeded market size (~450 g). FCE may have decreased for a number of reasons, however stocking density did not appear to be a factor affecting FCE in this study.

Studies conducted on other fish species have shown feed conversion and growth rate decrease when fish are reared at high densities. This suggests that fish-to-fish interactions may induce stress resulting in reduced growth. Because pompano are extremely active fish, stocking densities suitable for other cultured fishes may not be suitable for larger fish of this species. The stocking densities used in this study may have been low enough to reduce crowding-induced stress. Additional research should be conducted to determine if stocking density of pompano has an effect on digestion efficiency and growth rates, because stocking densities necessary to yield optimal growth of Florida pompano might not be profitable for commercial production.

It is possible that the sexual maturation of fish used in this study could have contributed to the decline in FCE and growth rate that was observed among fish in all treatment groups. Florida pompano from the Gulf of Mexico become sexually mature at about one year of age and ~350 g body weight (Dr. Edward Chesney, personal communication). Although it was not determined if the fish had become sexually mature during the study (they would have had to have been killed to make that determination), it is possible. If so, this could have affected their growth rates, which usually decline after sexual maturation.

A possible reason for poor digestion efficiencies and reduced growth rates of pompano (150-200 g) in previous studies could have been due to feed composition. Studies conducted by

Williams et al. (1985) and Lazo et al. (1998) revealed that a proper dietary balance of energy and protein is an important factor affecting optimal growth of juvenile pompano. Pompano (~ 0.5 g) fed diets containing digestible energy-to-digestible protein ratios between 7.4 and 8.1 gained more weight than pompano consuming diets above or below those ratios (Williams et al. 1985). A study of the effects of dietary protein level, conducted by Lazo et al. (1998) further supports this conclusion. Juvenile pompano fed diets (8% lipid) with increasing protein levels and corresponding lower energy-to-protein ratios, gained more weight when fed diets with lower energy-to-protein ratios (i.e., E:P ratio of 8.9 kcal/g protein).

Most species of fish exhibit reduced growth when fed diets with energy-to-protein ratios above or below an optimum ratio. Fish consuming diets deficient in energy catabolize dietary protein to meet energy needs, thereby reducing the amount of protein available for growth. A diet with an excessively high energy content will satisfy energy needs with less feed, thereby causing a reduction in feed consumption. As stated previously, many of the diets used in early studies consisted of ground trash fish or were formulated for freshwater species. It is likely that most of these diets contained energy levels below the suitable range.

The diet used in the present study appears to have had energy levels much higher than what pompano require as evidenced from their high levels of whole body lipid. Lipid content of fish in the present study was much higher than reported by Williams et al. (1985) or Lazo et al. (1998). Like many fishes, pompano are constantly in search of food. Fish depend on stored lipid as an energy source when feedings occur irregularly. Virtually all of the lipid of pompano reared in the present study was stored as muscle lipid; very little visceral fat was recovered. Fish consuming feed with excessively high energy levels use energy for maintenance and growth (Halver 1989). Excess protein that is not needed for growth is converted to lipid and may be stored in muscle tissue (Halver 1989). The active nature of pompano may be a reason for the observed lack of visceral fat in market-size fish. Also, because of their small visceral cavity, it is possible that pompano naturally store a majority of body lipid in muscle.

Male pompano have been shown to reach sexually maturity at weights of 269-469 g (Moe et al. 1968). Most of the reductions in digestion efficiencies encountered in previous studies occurred at the lower end of this size range. During sexual maturation, somatic growth slows and gonadal growth accelerates (Halver 1989). Energy that is normally utilized for muscle and tissue growth is channeled toward gonadal development. It is possible that the diets used in previous studies were inadequate to meet the energy requirements of sexually developing pompano. As pompano increase in weight, it is likely that the amount of energy needed to sustain body maintenance and gonadal or muscle growth also increases. The feed used in the present study may have supplied enough energy to support sexual development and sustain muscle growth to a size larger than that reported in previous studies. The maximum body weight that could be sustained efficiently by the feed used in these experiments appeared to be approximately 500 g.

FCE does not necessarily represent accurately the relationship between growth rate and feed consumption. FCE is a crude measure of diet utilization that can be influenced by a number of factors. In the present study, the amount of feed fed to each tank of fish was used in the calculation of FCE as feed consumed; in other words it was assumed that fish consumed all of the feed that was offered. Although care was taken to ensure the fish were not overfed, it is doubtful that all of the feed was consumed. For example, small particles of feed may have been overlooked by fish and subsequently removed during routine cleaning of tanks. As fish grew, the particle size of the crumbled feed became proportionally smaller and was likely more difficult for fish to see. Crumbled feed was used for a time when the fish were transferred to the 1,500-L tanks. It is likely that, due to the particle size of this diet compared to fish size, some of the ration was not consumed. In the calculation of FCE [(g weight gain/g dry feed fed) * 100], recording a higher amount of feed than was actually consumed results in the underestimation of FCE.

Mortality can also affect FCE. During Experiment 3, several fish escaped from experimental tanks and died. As a result, removal of these fish from the population altered the mean FCE of fish in some tanks. Because feed was distributed manually, daily feed amounts did not appear to change due to the absence of one fish. However, the largest fish in a given tank was observed to grow most rapidly. Removal of such a large fish from a population of approximately 10 fish reduced the mean weight and mean weight gain of fish in the tank. This in turn resulted in a decrease in FCE from the previous week.

A wide range of growth variation existed among individual fish at the termination of each experiment. The entire experimental fish population was hand-graded at the initiation of each experiment. Fish significantly smaller or larger than the mean weight of the population were removed and were not carried over to subsequent experiments. This was done to reduce initial size variation in each experiment. Even though fish were relatively uniform in size at the beginning of each experiment, the degree of size variation was large at the termination of each experiment. Fish weight at termination of Experiment 1 (mean weight, 61.7 g) ranged from 17.3 to 99.3 g. Fish weight at termination of Experiment 2 (mean weight, 201.6 g) ranged from 84.0 to 312.0 g. Weight of fish reared to market size (mean weight, 551.2 g) ranged from 300.0 g to 704.0 g. Fish weight at termination of Experiment 3 (mean weight, 712.0 g) ranged from 501.0 g to 1,040.0 g. Similar size variations of Florida pompano were reported by Berry and Iverson

(1969). In the present study, juvenile pompano with little initial size variation had weights ranging from 85 g to 305 g after 4.5 months of growth.

A high degree of size variation might be expected among fish that received a restricted diet. Larger, more dominant fish will likely consume a greater portion of feed. With restricted rations, it is doubtful that all fish consumed equal amounts of feed. However, the degree of size variation among fish fed to satiation also was higher than expected. Theoretically, unlimited rations should allow all fish to eat until satiated, resulting in similar growth rates. However, this was not observed in the present study. It is worthy to note that growth rates may be sex-determined. In most fish species, females weigh more than males of the same year class. The sex of fish in these experiments was not determined, so no correlation between sex and feed consumption could be made.

Temperature is a major factor to consider when evaluating the culture potential of any fish. Because pompano (~17 g initial weight) required 4.5 months to attain market size in recirculating systems in this study, consideration of open-air pond culture in the United States would be risky. Seasonal temperature changes and sudden cold fronts have the potential to reduce water temperatures to levels that could slow growth and cause high mortalities, even in the southernmost states. Therefore, indoor or greenhouse-based, recirculating culture systems may be most suitable for pompano aquaculture in the USA. Ambient temperatures of such systems can be controlled year round, with little influence from the outside environment. Water temperature control was not a problem in the present study. The air-heating units of the laboratory where the experiments were conducted were not used during the summer months when natural air temperatures were typically between 27 and 32 C.

Parasite treatments during the quarantine period were effective. The culture systems did become infested with *Trichodina* spp., but this gill parasite, even at moderate to high densities, is not lethal to pompano. However, if left untreated, *Trichodina* can interfere with oxygen transfer at the gills and lead to serious secondary, bacterial infections. The bi-weekly formalin treatments used in the present study would be impractical on a commercial scale. Parasites can multiply rapidly to lethal levels in closed systems and fish reared in those systems are vulnerable to parasitic outbreaks. Many of the treatments used to eliminate aquatic parasites are not approved for use with fish intended for human consumption. Research should be conducted to develop commercially-effective treatments that eliminate parasites from closed systems and that still allow the fish to be marketed for human consumption. Careful measures should be taken to ensure that fish remain free of parasites and that culture systems do not become contaminated. By establishing a pathogen-free seed stock, and maintaining clean rearing systems, parasitic infestations could be virtually eliminated in a commercial setting.

Research is also needed to determine the lowest range of salinities at which pompano can be efficiently grown. Facilities unable to utilize a natural supply of seawater must manufacture seawater from synthetic sea salts or concentrated saltwater. Manufacturing and maintaining high salinity water can be extremely expensive. Studies have shown that pompano are able to tolerate salinities near 0 g/L. It remains to be seen if pompano can grow as rapidly in brackish water as they did in the present study at a salinity of ~25 g/L. Lowering rearing salinities would reduce production costs and reduce problems with saltwater effluent, which is considered a pollutant when discharged into freshwater. Reducing the rearing salinity would make the effluent from pompano production facilities more environmentally acceptable.

Development of spawning techniques is another major step that is needed for pompano culture to expand. To be sold commercially, hatchery produced pompano must be grown to market size. Because of restrictions on the capture of wild juveniles, commercial pompano culture will require maintenance of brood stocks and artificial spawning. Captive spawning and larval rearing have been attempted with limited success. Most of the problems associated with larval rearing have occurred during hatchery development. Unfortunately, most of the success in this area has come from proprietary private research that is unavailable to the scientific community or commercial aquaculturists.

The ultimate goal of this study was to rear market-size pompano from fingerlings in closed recirculating systems. Because the three experiments were conducted with fish of different sizes, it is difficult to use the results to recommend a single grow-out period for production of market-size pompano. Results of this study suggest that four feedings to apparent satiation per day will yield market-size pompano more quickly and more efficiently than any of the other feeding strategies tested. However, four feedings to satiation per day may not be the most cost-effective method of producing market-size pompano. In general, feeding to satiation utilizes a greater quantity of feed than restriction feeding. Likewise, four feedings to satiation would require more diet (and labor) than two feedings to satiation.

Producers attempt to place their products on the market as quickly as possible. The scope of this study makes it difficult to estimate the time frame that would be needed to rear market-size pompano from fingerlings with only one feeding per day. Thus, it is difficult to estimate the amount of feed that would be utilized during grow-out with a single feeding regime. Even though four satiation feedings resulted in higher mean weight, two satiation feedings may prove more cost-effective on the basis of feed cost and labor. Two feedings per day, restricted or to satiation, would require less labor than four or six daily feedings. Automatic or demand feeders also could be used to reduce labor. These devices work well in tanks and raceways, but are not practical for most ponds.

Feed quality also may affect the rate at which Florida pompano attain market size. The feed used in these experiments was of very high quality. Pompano fed less expensive diets, containing lower lipid and protein levels, may require more feedings to achieve growth rates exhibited in the present study. Attention should be paid to the digestible energy-to-protein ratio of the feed to ensure that it is in a range suitable for optimal growth.

Ultimately, feeding regimes will likely be determined by the producer. Production costs and labor will factor into any feeding regime. While this study attempted to provide insight on the effects of different feeding strategies on growth of Florida pompano, it will be up to individual producers to develop feeding protocols that are cost-effective for their operations. Based on the results of these experiments, satiation feeding is recommended to efficiently grow Florida pompano to market size in the shortest amount of time.

The high market value of Florida pompano provides producers with a potentially high profit margin. With little competition from commercial fisheries, cultured pompano could meet market demand. Producers can expect $6.50 to $11.00 per kilogram for pompano in the round. Much of the sales would likely be generated by restaurants and food service institutions.

Results of this study indicate that market-size Florida pompano can be reared in closed recirculating systems. While many aspects of pompano culture still need to be investigated, pompano remains a promising species for aquaculture.

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APPENDIX
PROXIMATE COMPOSITION OF FEED

TABLE 11. Composition of feed used in Experiments 1-3. Values are means. Percentages are expressed on a dry weight basis.

Feed Type	Dry Matter (%)	Crude Protein (%)	Lipid (%)	Ash (%)
Crumble	8.0	56.5	13.8	13.1
Pellet	8.3	54.9	13.3	12.9

VITA

Derek R. Groat was born in Buffalo, New York, on November 24, 1977. He is the son of Robert and Carol Groat and has an older sister, Jennifer. He attended Silver Creek Central School and graduated in 1996.

He was admitted to Long Island University, Southampton College in September 1996. As an undergraduate, he took part in a Co-Op at Jenkinson's Aquarium in Point Pleasant, New Jersey during the summer of 1997. In the spring semester of 1998, he participated in a nine-week semester-at-sea program. During the spring of 1999, he interned in the aquaculture department at Mote Marine Laboratory, Sarasota, Florida. In May 2000, he graduated with a Bachelor of Science degree in marine biology.

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